Emergency and Disaster Response to Chemical Releases

Technician Level Training

29 CFR 1910.120 (q)

Module 2

Toxicology

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Table of Contents

Acronyms Used in This Module....5
Overview....7
Terminal Learning Objective....7
Enabling Objectives....7
Toxicology....9
Exposure Limits....9
  Permissible Exposure Limit (PEL)....10
  Threshold Limit Value (TLV)....10
  Recommended Exposure Limit (REL)....10
  Short-Term Exposure Limit (STEL)....10
  Ceiling (C)....11
  Immediately Dangerous to Life and Health (IDLH)....11
Toxicity Relationships....12
Acute Exposure Guidelines (AEGLs)....13
Military Air Guidelines (MAGs)....14
Dose Response....14
  Lethal Dose 50% (LD50)....15
  Lethal Concentration 50% (LC50)....15
    Highly Toxic....16
    Toxic....16
Routes of Entry....16
  Inhalation....17
  Ingestion....17
  Injection....17
  Absorption....17
Acute and Chronic Exposure....17
  Acute Exposure....18
  Chronic Exposure....18
Health Hazards....18
  Asphyxiants....19
  Carcinogens....19
  Flammable....19
  Irritants....19
  Sensitizers....19
  Mutagens....19
  Teratogens....20
  Target Organ Poisons....20
Dissemination of Chemical Agents/TICs....21
  Physical Forms....21
    Vapors and Gases....21

Aerosols and Sprays 22
Liquids 22
Solids 22
Dissemination Systems and Devices 23
Military-Type Munitions 23
Energetic/Explosive Devices 23
Commercial Delivery Systems 24
Breaking Devices 25
Dumping or Placing 25
Binary Devices 26
Protection From Chemical Toxins 26
Factors Affecting Human Response to Chemical Exposure 27
The Chemical Itself 27
Type of Contact 27
Chemical Dose 27
Individual Sensitivity 27
Interaction With Other Chemicals 28
Mechanisms of Injury or Harm 28
Thermal 28
Radiological 28
Asphyxiant 28
Chemical 29
Etiologic 29
Mechanical 29
Psychological 29
Summary 29
Appendix A 31

Acronyms Used in This Module

ACGIH	American Conference of Governmental Industrial Hygienists
AEGL	Acute Exposure Guidelines
ALARA	As Low As Reasonability Achievable
C	Ceiling
CBRNE	Chemical, Biological, Radiological, Nuclear, Energetic/Explosive
CFR	Code of Federal Regulations
DDT	Dichlorodiphenyltrichloroethane
DOT	Department of Transportation
EOP	Emergency Operations Plan
EPA	Environmental Protection Agency
HAZWOPER	Hazardous Waste Operations and Emergency Response
HASP	Health and Safety Plan
ICS	Incident Command System
IDLH	Immediately Dangerous to Life and Health
LC50	Lethal Concentration 50 percent
LD50	Lethal Dose 50 percent
MAGs	Military Air Guidelines
mg/kg	milligrams per kilogram
mg/m^3	milligrams per cubic millimeter
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PPE	Personal Protective Equipment
PCB	Polychlorinated Biphenyl
PPM	Parts Per Million or (ppm)
REL	Recommended Exposure Limit
RCRA	Resource Conservation and Recovery Act
RQ	Reportable Quantity
SARA	Superfund Amendments and Reauthorization Act
SCBA	Self-Contained Breathing Apparatus
SOP	Standard Operating Procedures
STEL	Short-Term Exposure Limit
TSCA	Toxic Substance Control Act
TICs	Toxic Industrial Chemicals
TIMs	Toxic Industrial Materials
TLV	Threshold Limit Value
TWA	Time-Weighted Average
VX	Venom X: any number of chemical compounds (nerve agent)

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Overview

An understanding of routes of entry and knowing the symptoms of exposure and the factors that affect human response to chemical exposure is vital. Applying this knowledge with safe work practices will give the responder ability to operate safely day to day.

Terminal Learning Objective

Upon completion of this module, the participant will be able to recognize the signs and symptoms of exposure to various chemical agents and toxic industrial chemicals, terms, definitions, and characteristics of these chemicals.

Enabling Objectives

- Provide a definition for the following:
    - Dose Response/LD50
    - Permissible Exposure Limits (PEL)
    - Threshold Limit Value (TLV)
    - Time-Weighted Average (TWA)
    - Short-Term Exposure Limit (STEL)
    - Immediate Danger to Life and Health (IDLH)
- Differentiate between the “acute” and “chronic” effects of exposure to TICs, TIMs, and CBRNE agents.
- Identify the four routes of exposure.

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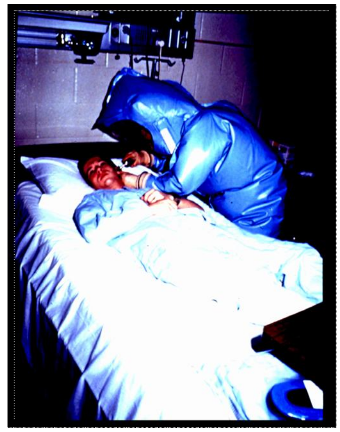
Toxicology



Toxicology is the study of chemical toxicity. Toxicity is the degree to which a chemical or substance has a harmful effect on living things. All of the information known today about toxic effects of chemicals and other hazardous substances has been gathered from two sources of information:

- *Epidemiological studies,* where numbers of affected people in one group are compared to numbers of affected people in another group. Sometimes the information comes from actual exposures to a chemical in the workplace.

- *Animal studies*, which provide most of what we know about the dangerous effects of toxic substances. Humans, however, may react differently than animals to exposure to toxic materials.

Exposure Limits

Exposure limits are measurements derived from human studies, animal studies, and computer models that identify safe and unsafe levels of chemical exposure to workers. Exposure limits are established by government entities and other recognized bodies that carry the weight of law and are enforced by OSHA, EPA, and other regulatory bodies. It is difficult, if not impossible, to predict the effect of any chemical on a particular person, but exposure limits are designed for the healthy working adult.

There are three principal agencies that publish exposure limit data:

- The Occupational Safety and Health Administration (OSHA)

- The National Institute of Occupational Safety and Health (NIOSH)

- The American Conference of Governmental Industrial Hygienists (ACGIH)

It is common for these agencies to agree on an exposure level for a chemical. On some occasions they do not agree; in those cases the responder should protect to the lowest published level.

Permissible Exposure Limit (PEL)

The PEL is an exposure limit published by OSHA. It is defined as the maximum exposure level for an employee who works an 8-hour day and a 40-hour week. The PEL is also a time-weighted average (TWA), which means the exposure may actually be over the PEL for a period of time, but the average exposure to the chemical cannot be over the PEL for an 8-hour work day or 40-hour work week.

Monoethylamine is a liquid below 62 degrees Fahrenheit and is used in the production of rocket fuel, medicine, and rubber. The PEL of monoethylamine is 10 parts per million (ppm). For working purposes, it can be assumed that the smaller the PEL, the higher the hazard to the worker. Ethyl alcohol, the alcohol in alcoholic beverages, has a PEL of 1,000 ppm, so it is fair to say that monoethylamine is 100 times more toxic than ethyl alcohol. On the other hand, no occupational safety organization publishes a PEL for sarin, a chemical weapon. According to the NIOSH Emergency Response Card, the U.S. Military uses 0.000017 ppm as a TWA exposure, an average similar to a PEL.

Threshold Limit Value (TLV)

The TLV is an exposure limit published by the ACGIH. TLVs are based on 8-hour work days and 40-hour weeks.

Recommended Exposure Limit (REL)

The REL is an exposure limit published by NIOSH. It is defined as a time- weighted average concentration for up to a 10-hour workday during a 40- hour work week. RELs, along with many PELs, can be found in the NIOSH Pocket Guide. The REL for yellow phosphorous is 0.1 mg/m^3. Yellow phosphorous is transported in water because it spontaneously ignites in air. If a container of yellow phosphorous is found by a disaster site worker, the container should not be handled without a thorough hazard assessment and a safety and health response plan. Safe work practices following the emergency response plan (ERP) is imperative.

Short-Term Exposure Limit (STEL)

The STEL is an exposure limit published by the ACGIH and is defined as a 15-minute time-weighted average that should not occur more than four times per day. Each of the four 15-minute exposures per workday should be separated by at least one hour.

Chlorostyrene is colorless liquid that is toxic to the liver with a TLV of 50 ppm. Its STEL is 75 ppm. A responder may have short exposures up to

75 ppm but cannot exceed a 50 ppm average exposure for the workday per workweek.

Ceiling (C)

Some chemicals have a PEL along with a ceiling level. A PEL is an average over a workday. The ceiling is an exposure level that cannot be exceeded during any part of the work shift without adequate personal protective equipment. If the worker's environment cannot be monitored continuously, it must be tested every 15 minutes.

Immediately Dangerous to Life and Health (IDLH)

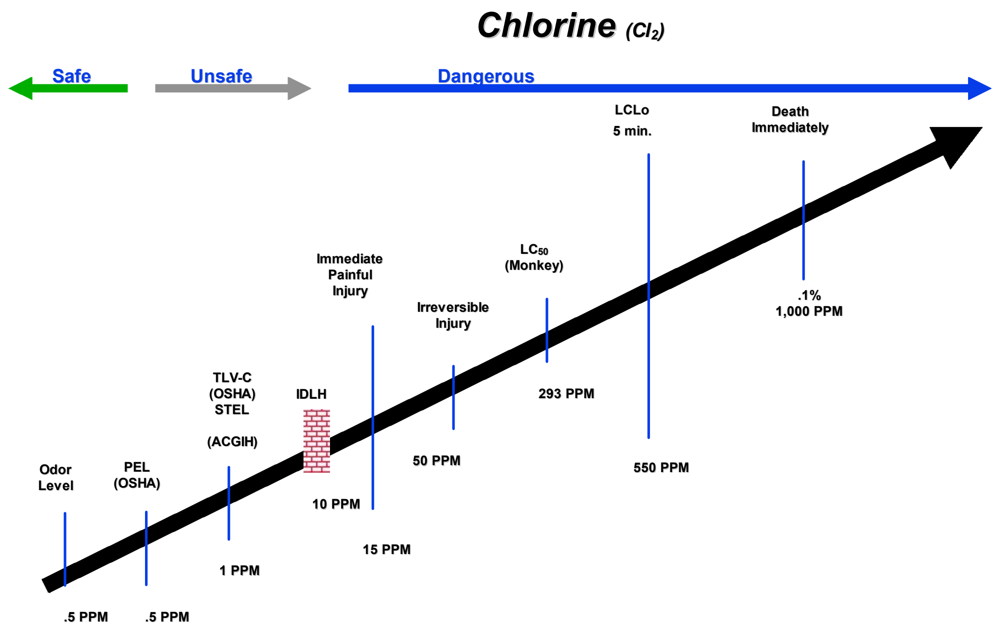
Immediately Dangerous to Life and Health is an exposure level that poses a serious risk to the worker's life and health. If a worker is exposed to an IDLH level of any chemical, he should stop his task and exit to a safe area immediately.

According to the NIOSH pocket guide, IDLH values are based on the effects that might occur as a consequence of a 30-minute exposure. However, the 30-minute period was not meant to imply that workers should stay in the work environment longer than necessary. In fact, every effort should be made to exit immediately. Additional information on IDLH can be found in the NIOSH Pocket Guide to Chemical Hazards.

IDLH levels can be found in the NIOSH Pocket Guide for many chemicals. No worker should work in an area with an IDLH atmosphere without a positive pressure SCBA.

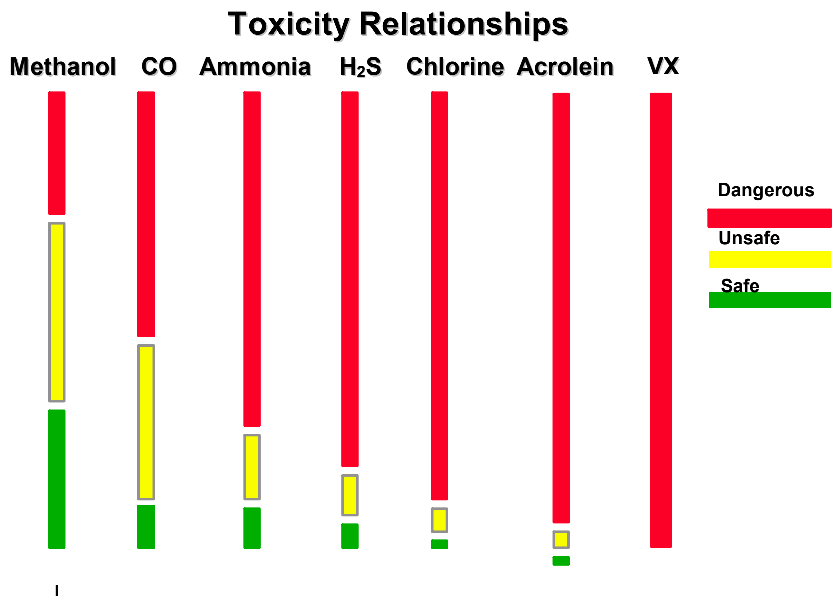
Toxicity Relationships

The following chart depicts a poison line for chlorine gas showing safe, unsafe, and dangerous exposure concentrations.



Toxicity Relationships (ppm)			
Chemical	**TLV-C**	**IDLH**	**Fatal**
Chlorine	0.5	25	1000
Hydrochloric Acid	10	100	2000
Ammonia	25	300	10000
Carbon Monoxide	35	1200	10000
Acrolein	0.1	5	
VX Nerve Agent	0.00001	0.0001	

The preceding chart presents some chemicals disaster site workers might come in contact with while performing their duties. Notice that some are more typical chemicals like hydrochloric acid, and others like VX nerve agent are more exotic. Both chemicals can harm a person, but VX is toxic in smaller quantities. The following chart displays this toxic relationship.



Acute Exposure Guidelines (AEGLs)

AEGLS are exposure limits that are promulgated by the EPA. They are intended to provide “threshold exposure limits for the general public and are applicable to emergency exposure periods ranging from 10 minutes to eight hours” according to the Federal Register published on December 13, 2000 (Volume 65, Number 240).

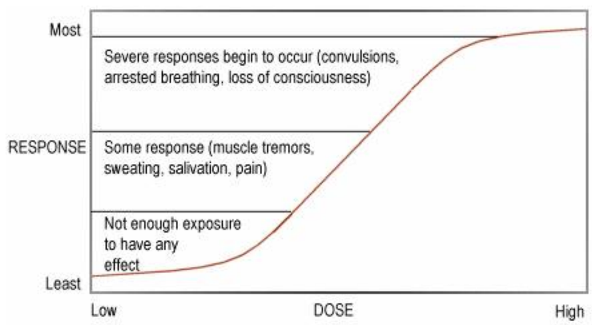
The difference between AEGLs and the permissible exposure limits (PELs) discussed previously is their intended audience. PELs and others are intended for the worker to use throughout their working life. An AEGL is designed for use by emergency responders on a one-time exposure from 10 minutes to eight hours in duration. They are helpful in predicting casualties and deciding whether to evacuate or hold the population in place after an incident.

Military Air Guidelines (MAGs)

Military Air Guidelines are exposure levels designed for military commanders to use when making “go/no go” decisions for their troops. They predict the response of a chemical exposure to physically fit adult male and female soldiers between the ages of 18 and 55.

MAGs should not be used as a safe/unsafe guideline for responders. While they can provide additional information, responders should use exposure guidelines designed for workers and chemical handlers promulgated by OSHA, NIOSH, ACGIH, and other recognized authorities.

Dose Response



The dose of a chemical can be defined as the quantity of chemical administered over a given time. A high quantity exposure over a short time or a low quantity exposure over a longer time may cause the responder a wide variety of problems.

Whenever the term toxicity is used, "dose" is generally incorporated. Dose response in chemical toxicity terms is similar to dose in radiological terms. It is related to the quantity of a material and how long it is received. The higher the chemical dose, the greater the toxic reaction.

Toxic dose is often defined as LD50 or LC50. LD50 stands for *Lethal Dose 50%* and LC50 for *Lethal Concentration 50%*. A number given as an LD50 or LC50 would refer to the specific amount of a particular material that results in the deaths of 50 percent of a sample group of laboratory animals. For example, an LC50 of 25 mg/m^3 means that a concentration of 25 mg/m^3 of a certain substance has shown to be fatal to 50 percent of a test group of animals. Please note that the smaller the number the more toxic the material.

TOXIC CONCENTRATION

Less than 1.0 mg/kg	Dangerously toxic
1 - 50 mg/kg	Highly toxic
50 - 500 mg/kg	Toxic
500 - 5,000 mg/kg	Moderately toxic
5 - 50 g/kg	Low toxic

Lethal Dose 50% (LD50)

The LD50 is a dose of a chemical that will be fatal to 50 percent of a group of laboratory animals over a given period of time. Sometimes LD50s will be reported as "oral LD50," which means the dose was given orally. A "dermal LD50" is absorbed through the skin. It is usually given in terms of milligrams of chemical per kilogram of bodyweight.

Lethal Dose 50% of Selected Chemicals

	Route	Dose	Test Subject
MEK	Oral	2737 mg/kg	Rat
Sulfuric Acid	Oral	2140 mg/kg	Rat
Morphine	Oral	461 mg/kg	Rat
Propylene Oxide	Oral	440 mg/kg	Rat
Ammonia	Oral	350 mg/kg	Rat
Ethylene Oxide	Oral	72 mg/kg	Rat
Amphetamine	Oral	50 mg/kg	Rat
Sarin	Skin	1700 mg	Human
Soman	Skin	50 mg	Human

Lethal Concentration 50% (LC50)

The LC50 is similar to an LD50 in that it will be fatal to 50 percent of a group of laboratory animals over a given period of time. The difference is that an LC50 is an inhaled dose for the laboratory animals instead of an ingested or absorbed dose. The LD50 and LC50 are limited in their practical application but can be useful in determining the relative toxicity of a chemical.

Lethal Concentration 50% of Selected Chemicals			
Chemical	**Dose**	**Time**	**Test Subject**

Benzene	10,000 ppm	7 hours	Rat
Hydrogen Chloride	5666 ppm	30 min	Rat
Sulfur Dioxide	2520 ppm	1 hour	Rat
Ethylene Oxide	800 ppm	4 hours	Rat
Chlorine	293 ppm	1 Hour	Rat
Sulfuric Acid	510 mg/m^3	2 hours	Rat
Nitric Acid (Red Fuming)	67 ppm	4 hours	Rat
Soman	70 mg/m^3	2 – 10 min	Human
VX	15 mg/m^3	2 – 10 min	Human

Highly Toxic

A chemical that has an LD50 (lethal dose 50%) of 50 milligrams of chemical per 1 kilogram of body weight administered orally; LD50 of 200 milligrams or less per kilogram of body weight when administered by continuous skin contact for 24 hours; LC50 (lethal concentration 50%) in air of 200 ppm by volume or less when administered by continuous inhalation for one hour or less; or 2 mg/kg per liter or less of mist, dust, or fume when continuously inhaled for one hour or less.

Toxic

A chemical that has an LD50 (lethal dose 50%) of more than 50 milligrams/kg but less than 500 mg/kg of chemical per 1 kilogram of body weight administered orally (see chart on page 2-2); LD50 of more than 200 milligrams per kilogram of body weight but less than 1,000 mg/kg when administered by continuous skin contact for 24 hours; LC50 (lethal concentration 50%) in air of more than 200 ppm by volume but less than 2,000 when administered by continuous inhalation for one hour or less; or more than 2 mg/kg per liter but less than 20 mg/kg of mist, dust, or fume when continuously inhaled for one hour or less.

Routes of Entry

For a person to receive a chemical dose, they must be exposed in one of four ways: inhalation, ingestion, absorption, or injection. Knowing how hazardous materials can enter and react with your body is critical to your life safety.

Inhalation

The most common route of entry for the worker is inhalation. Inhalation of a chemical occurs when contaminated air enters a worker's mouth or nose.

Chemicals like Mace will irritate the upper airway structures and cause mucus secretions in the lower airways that can lead to choking and shortness of breath. Other chemicals do not have adequate warning properties. They can damage the worker with no perceptible odor, taste, or pain sensation. An example is carbon monoxide.

The disaster site worker's defenses against chemicals posing an inhalation hazard are environmental controls that remove the hazard from the worker's environment and frequent chemical monitoring. If environmental controls will not adequately remove contaminants from the air, workers should wear appropriate respiratory protection.

Ingestion

Ingestion is the intentional or inadvertent consumption of chemicals. It is the most common route of entry for chemicals in the home. Most ingestion injuries are caused by poor personal hygiene. Proper hygienic practices will prevent a worker from ingesting chemicals on the scene. Responders should always wash their hands before eating or drinking.

Injection

Injection can occur when a chemical enters the body through a wound or an abrasion. Injection can also occur from a needle stick or other skin piercing device including high pressure pneumatics and hydraulics.

Absorption

Absorption occurs when a chemical enters the body by dermal or skin contact. Responders can protect themselves from chemical absorption by wearing proper personal protective equipment. The eyes and mucus membranes are most vulnerable to this type of exposure.

Acute and Chronic Exposure

There are two different types of exposure, acute and chronic. Acute exposure typically brings on a sudden onset of symptoms. Chronic exposure occurs with repeated exposure over a period of time and results in generally less obvious symptoms during the exposure.

Acute Exposure

While there are no hard and fast rules that differentiate an acute exposure from a chronic exposure, acute exposure is generally characterized by a one-time, high-dose exposure. The resulting symptoms of exposure are usually observed within 24 to 48 hours of exposure. Some common symptoms of an acute exposure are:

- Skin rashes
- Burns
- Rapid onset shortness of breath
- Pain
- Swelling
- Unresponsiveness
- Death

Chronic Exposure

Chronic exposures are characterized by small doses of a chemical repeated many times usually over a period of years. The effects of exposure do not occur as rapidly as an acute exposure, but the cumulative effect can be just as severe. The best protection against any chemical exposure is safe work practices and proper personal protective equipment.

Health Hazards

Health hazards may cause measurable changes in the body such as decreased pulmonary function (breathing). These changes are generally indicated by the occurrence of signs and symptoms, such as shortness of breath, in exposed workers. It is important to understand that some chemicals may fall into more than one category.

Asphyxiants

Asphyxiants are chemicals that deprive the victim's body tissues of oxygen. An asphyxiant interferes with the body's ability to transport or use the oxygen carried by the blood stream. Any gas heavier than air can easily displace oxygen and cause asphyxiation. Examples of chemical asphyxiants are carbon monoxide and hydrogen cyanide.

Carcinogens

Chemicals in this category are known to cause cancer in humans or in laboratory test animals. This is a chronic effect because there is a time period that elapses before a malignant tumor will appear. Examples of carcinogens are benzene, benzo(a)pyrene, asbestos fibers, acrylonitrile, and DBCP (dibromochloropropane).

Flammable

Flammable liquids are defined as any liquid having a flashpoint below 140^{o}F. Examples of flammable liquids are vinyl acetate, acetone, and gasoline.

Irritants

This group of chemicals will irritate various tissues causing redness, rashes, swelling, coughing, or even hemorrhaging. Chlorine and ammonia are two examples of irritants.

Sensitizers

Another name for sensitizers is allergens. These chemicals cause an allergic type of reaction due to sensitivity from prior exposure. An acute response may be swelling of the breathing tubes, which causes breathing difficulty. Sensitizers can cause chronic lung disease. Some common examples are epoxies, aromatic amines, formaldehyde, nickel metal, and maleic anhydride.

Mutagens

Mutagens cause alterations in the genes of a person exposed. The result may be malfunction of a specific organ or tissue, depending upon the type of cell the mutation took place. Gene damage can be passed on to children if the mutation occurred in either the sperm or egg of the parents. Examples of mutagens are ethylene oxide, benzene, and hydrazine.

Teratogens

Teratogens cause damage or death to a developing fetus. This damage cannot be passed on to further generations because it does not affect the genetic code. Examples of teratogens are thalidomide, dioxins, lead, and cadmium.

Target Organ Poisons

Many chemicals will target a particular tissue or organ and cause disease or damage at that location. The following examples are listed according to the tissue or organ affected.

Lungs - Asbestos fibers and silica dust may cause a fibrosis effect in the lung tissue. Fibrosis is a condition in which the lung becomes scarred and inflexible, making the lung unable to expand and contract.

Skin - A condition called chloracne may be caused by repeated exposures to PCBs (polychlorinated biphenyls) and other chlorinated hydrocarbons.

Eyes - Lachrymators are chemicals that can cause instant tearing at low concentrations. Examples are tear gas and Mace. Other chemicals can cause cataracts, optic nerve damage, and retinal damage by circulating through the bloodstream and reaching the eye. Examples are naphthalene, methanol, and thallium.

Central Nervous System - Chemicals affecting this system containing the brain and spinal cord are called neurotoxins. Neurotoxins affect the neurons that carry electrical signals by inhibiting their function. This can cause behavior changes, emotional changes, alterations in walking, and loss of hand/eye coordination. A condition called anoxia may occur, due to a lack of oxygen flow to the brain cells. A lack of oxygen results in cell death. Examples of chemicals causing central nervous system effects are tetraethyl lead, chlorinated hydrocarbon pesticides (e.g., DDT), malathion, lead, and mercury.

Liver - Substances that are capable of damaging the liver are called hepatotoxins. The liver is the main processing organ for toxins. It may convert toxics into nontoxic forms; however, the liver may generate a more toxic by-product, which can cause cellular and tissue damage. Examples of hepatotoxins are carbon tetrachloride, chloroform, tannic acid, and trichloroethylene. Examples of chemicals that cause cirrhosis (a fibrotic disease that results in liver dysfunction and jaundice) are carbon tetrachloride, ethyl alcohol, and aflotoxin. Other effects can range from tumors to enlargement of the liver and fat accumulation.

Kidneys – The main function of the kidneys is to filter blood and eliminate wastes. Because waste gets concentrated in the process, toxins can be at much higher levels in the kidneys. Toxins that damage this organ are known as nephrotoxins. Most heavy metals fall into this category, including mercury, arsenic, and lithium. Many halogenated (i.e., chlorinated) organic compounds are also nephrotoxins such as tetrachloroethylene, carbon tetrachloride, and chloroform. Other chemicals that damage the kidneys include carbon disulfide, methanol, toluene, and ethylene glycol.

Blood - Substances capable of producing blood disorders are called hematoxins. Chemicals that affect bone marrow, which is the source of most of the components of blood, are arsenic, bromine, methyl chloride, and benzene. Chemicals that affect platelets, which are cell fragments that help in the process of blood clotting, are aspirin, benzene, and tetrachloroethane. Chemicals that affect white blood cells, which help the body defend against infection, are naphthalene and tetrachloroethane.

Arsine, naphthalene, and warfarin can affect red cells, which carry oxygen throughout the body. Effects in the exposed individual may include (1) reduced red blood count, or anemia; (2) reduced white blood cell count, which leaves the victim susceptible to disease; and (3) reduced platelet count, which increases the possibility of hemorrhaging.

Reproductive Organs - Reproductive toxins can cause sterility, infertility, or spontaneous abortions. They can also affect an individual's hormone levels and activity. Examples of male reproductive toxins are mercury, lead, DDT, PCBs, dioxin, benzene, toluene, and xylene. Examples of female reproductive toxins are DDT, PCBs, parathion, and diethylstilbestrol.

Dissemination of Chemical Agents/TICs

Generally speaking, a chemical weapon is comprised of two parts: the chemical agent and the means of delivery. Chemical agents can be disseminated in a wide range of forms using many different delivery systems.

Physical Forms

Chemical agents can be delivered in any physical form: vapor, gas, aerosol, spray, liquid, or solid.

Vapors and Gases

Vapors and gases are slightly different. Gases are materials in the gaseous state that remain gases when compressed at ordinary temperatures. Vapors are produced by evaporating liquids or sublimating solids.

Both resume liquid or solid state under high pressure at ordinary temperatures. However, the terms “vapor cloud,” “vapor,” and “gas” are often used interchangeably.

Aerosols and Sprays

Aerosols and sprays are liquid droplets or dry particles suspended in air that are released into the air upon delivery. The difference is in the size of the droplets/particles released by the device nozzle. Aerosols have droplets/particles small enough to remain suspended and inhaled. Sprays have bigger droplets/particles that fall to the ground quickly and are more likely to contaminate surfaces and be absorbed through the skin or be ingested.

Liquids

Many agents are liquids at normal temperatures and pressures. Others are solutions of solids or viscous liquids. They are dissolved to improve flow characteristics and make them easier to disseminate. Liquid agents can be dispersed as liquids (e.g., to form pools or saturate the ground) or as aerosols that act like gases (to be inhaled). Most liquid agents are somewhat volatile (i.e., they form a vapor easily as they evaporate), and their volatility increases with higher temperatures. The resulting vapor cloud is hazardous.

Solids

Solids may take the form of particulates (i.e., powder) that can be inhaled or absorbed through mucous membranes, eyes, or sweat-dampened skin. They can also be dissolved to form liquid agents. In the form of powder or solution, these agents can be dispensed as aerosols.

Most chemical agents used as weapons are liquids. Delivering a chemical agent as a cloud of droplets, especially if disseminated in an enclosed public space, has the greatest potential for mass casualties.

Dissemination Systems and Devices

Chemical agents can be disseminated using a wide variety of system devices, ranging from quite sophisticated to very simplistic. The following are some examples of possible ways to deliver chemical agents.

Military-Type Munitions

Chemical munitions are designed to convert bulk chemical agents into an aerosol or spray that can contaminate large areas, penetrate the skin, and be inhaled. Weaponization involves several steps:

- Adding stabilizers to prevent degradation of the agent
- Adding thickeners to increase viscosity and persistence of the liquid agent
- Adding carriers to improve dispersion characteristics
- Inserting the agent into appropriate munitions

Common military munitions may be used, including aerial bombs, artillery shells, rockets, missiles, grenades, and mines. They can be designed in the form of a stationary bomb on the ground, an aerial bomb (exploding while still airborne to disperse the agent in air for inhalation or exploding on impact), or a land mine. With the increasing possibility of military supplies reaching the hands of terrorists through theft, seizure, or sale, use of such munitions for chemical terrorism is a growing possibility.

Energetic/Explosive Devices

In addition to military munitions, a variety of other explosive devices may be used to spread the chemical agent. Such devices would ordinarily include a small rupture charge surrounded by the agent and activated by a fuse, timer, or other device. When the rupture charge goes off, it bursts the device and disseminates the chemical agent. Examples include:

- Packaging the agent with a small explosive charge (e.g., a package bomb or suitcase bomb).

- Crashing and exploding a truck loaded with large amounts of a nerve agent.
- Packaging chemical agents as a contaminant in a shrapnel weapon (e.g., a nail bomb).

Note: After dissemination by explosive force, part of the agent will remain liquid, part will be aerosolized, and part will evaporate to form a vapor. This usually results in a significant loss of the chemical agent. The primary objective of using an explosive device is to scatter the agent in a vapor cloud and/or to heavily contaminate an area.

Commercial Delivery Systems

Because a small quantity of chemical agent can inflict a large number of casualties, commercial delivery systems can effectively be used to deliver the agent. Many such systems are dual purpose, easy to obtain, and easy to adapt for terrorist purposes. They pose a significant threat even though they are less efficient and less reliable than munitions delivery systems. Examples of such systems include:

- Crop-dusting aircraft.
- Weather balloons.
- Small aerosol generators (e.g., a pesticide generator used to spray orchards from a pick-up truck). Such generators can be air, ground, or watercraft-based.
- Suitcase generators (able to contaminate rooms or buildings).
- Pump-type pressure sprayers (e.g., garden chemical or paint sprayers available at hardware stores).

- Hand-held aerosol generators (e.g., deodorant spray cans).

- Hand-held liquid spray gun similar to a tear gas dispenser.
- Placement of a remotely activated sprayer in an air ventilation system.

Breaking Devices

Breaking devices include:

- Encapsulating a chemical agent in a breakable object (e.g., light bulb, thermos bottle).
- Microencapsulating a chemical agent to be activated by direct contact (e.g., similar to "scratch-and-sniff").

Dumping or Placing

Dumping or placement methods include:

- Placement an open gas cylinder, using the wind or a fan to carry a gas cloud toward victims.
- Dropping an open container of a liquid agent from a high place (e.g., a balcony, an airplane or helicopter) into a crowded area, such as an open stadium or hotel atrium.
- Placement of an agent in a closed public space (e.g., airport terminal, shopping mall, convention center, arena, subway station) to evaporate. The rate of evaporation may be quite slow, however, resulting in few exposures to high concentrations.
- Creating a pool of liquid agent using a hose and pump system.
- Insertion of chemical agents in foodstuffs (e.g., production lines at packaged food factories, dairies, meat processing plants, bottlers). Poisoning an entire water supply is considered unlikely, because of the large amounts of agent it would require. However, a private water supply (e.g., for a building) could be effectively targeted.

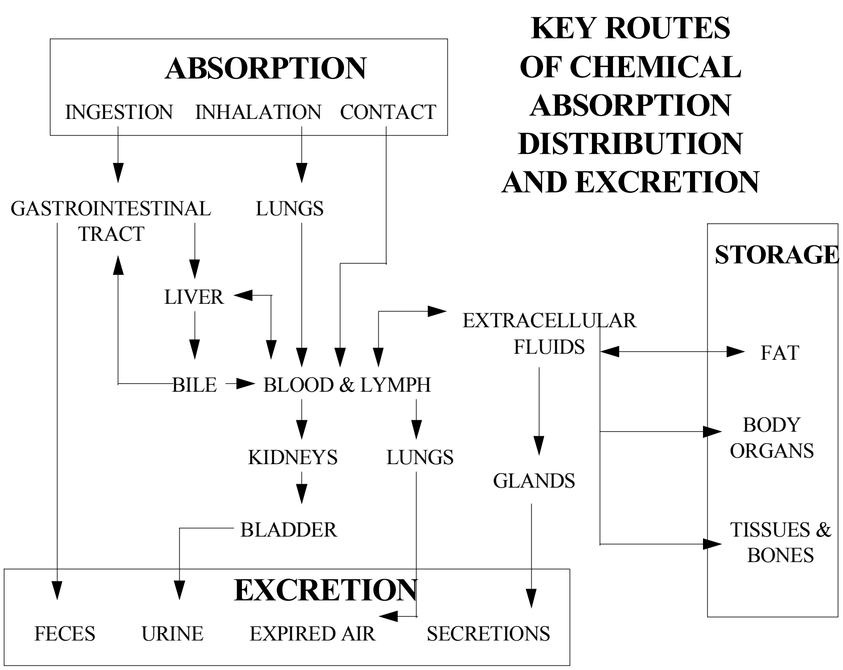
Binary Devices

In binary devices, two chemical precursors are kept separate until the last moment, when they are mixed and allowed to form the harmful chemical agent. Binary munitions (i.e., artillery shells, bombs, etc.) have been developed for several nerve agents. The 1995 Tokyo sarin incident used a simple binary device package containing plastic pouches of chemicals that, when punctured with a needle-tipped umbrella, released their contents and formed deadly sarin gas. Casualties included 12 dead and 1,100 injured, some permanently scarred.

These examples illustrate the flexibility of chemical agents as weapons of terrorism, and other methods are certainly possible. Although feasible delivery methods would seem to be limited by the terrorists' concern for personal safety (i.e., whether they could effectively protect themselves from the effects of their own attack), terrorists willing to sacrifice themselves in the process of harming others would have many other options.

Protection From Chemical Toxins

The human body can break down, detoxify, or eliminate many harmful chemicals if the dose is not too great. At the same time, we know that exposure to toxins puts stress on the body.



You must know the potential for toxicity of the materials that you work with to adequately protect yourself from toxic exposure. Once the presence and the concentrations of specific chemicals or classes of chemicals have been established, the associated hazards should be determined.

Most of us learn about acute toxicity very rapidly because we soon experience reactions from our body. Unfortunately, we do not learn the same way about chronic chemical hazards. Chronic hazards take years to reveal their damage so it is important to protect ourselves by understanding the written warnings that are available.

When the hazard is known, the hard part is over. However, you cannot adequately protect from the unknown. One can protect against known hazards by practicing the following:

- Use engineering controls provided, such as ventilation systems.
- Use safe work practices around chemicals.
- Select and use protective equipment based on safety officer recommendations.
- Wash exposed areas thoroughly before eating or drinking.

Factors Affecting Human Response to Chemical Exposure

The Chemical Itself

Some chemicals produce immediate and dramatic biological effects. Others may produce no observable effects or may be delayed in their appearance.

Type of Contact

Certain chemicals appear harmless in one form of contact, such as carbon monoxide on the skin. However, carbon monoxide inhaled into the lungs has much more serious effects.

Chemical Dose

The dose of a chemical exposure is simply related to the amount of chemical and the length or time of exposure.

Individual Sensitivity

Humans and other living animals vary in their response to any exposure to a chemical substance. For some, a certain dose may produce symptoms of serious illness; for others only mild symptoms may appear, or there may be no noticeable effect at all. Often a prior exposure to a chemical affects the way an individual responds to being exposed at a later time. Thus, there is not only variation between different individuals, there may be different responses in the same individual at different exposures.

Interaction With Other Chemicals

Chemistry is the study of the interaction of various chemicals with one another. An example is the reaction between acids and bases. The physical and biochemistry of the living organism is much the same. Chemicals in combination may produce different biological responses than responses seen when exposure is to one chemical.

Mechanisms of Injury or Harm

Hazardous materials are capable of harming people, property, and the environment. Toxic substances can enter our bodies through four routes of entry as we have identified. Regardless of the many things that can happen, the mechanisms of harm fall into seven types of causes:

- Thermal
- Radiological
- Asphyxiant
- Chemical
- Etiologic
- Mechanical
- Psychological

Thermal

Thermal refers to those events related to temperature extremes. High temperatures are common at fire-related incidents; however, we often forget or ignore the potential for injury from extreme cold.

Radiological

Energy released from radioactive sources such as alpha, beta, gamma, or neutron radiation can seriously harm the body. Often these harmful results can be long-lasting and may lead to death.

Asphyxiant

Many materials can displace oxygen when released in confined environments; examples are nitrogen, carbon dioxide, and natural gas. Asphyxiation can occur when chemicals interfere with the respiratory process. For example, carbon monoxide reduces the oxygen-carrying ability of the blood, and cyanide prevents oxygen from being used by body tissues.

Chemical

Most hazardous chemicals cause injury by reacting with body tissues to alter the structure or function of cells and their components. For example, exposure to a corrosive substance such as nitric acid can cause severe and deep tissue burns or permanent eye damage. Hydrofluoric acid can cause bone damage, whereas anhydrous ammonia causes internal burns, and parathion damages the nervous system.

Etiologic

Etiologic refers to uncontrolled exposure to living, disease-causing microorganisms. Diseases commonly associated with etiologic harm include hepatitis, typhoid fever, and a number of influenza viruses. Some of the more frightening etiologic agents are associated with germ warfare.

Mechanical

Some chemicals produce "mechanical" injury leading to tissue damage and cell death. For example, sulfuric acid can cause violent dehydration of cells because of strong attraction to water. Mechanical can also refer to injuries caused by shock waves, impact forces, or scattering of debris such as shrapnel from an explosion or blast. This avenue of harm must be considered in light of possible contamination as well as injury. The lacerations or punctures to the skin from a mechanical agent can lead to complications if injurious substances penetrate the skin.

Psychological

Though not a direct outcome of contact with hazardous materials, psychological factors are identified as a mechanism of harm. Stress is a frequent outcome of responding to disaster events.

It is important to understand the mechanisms of harm in order to properly diagnose and treat individuals who have come into contact with hazardous materials. Test your understanding by completing the exercise found in Appendix A of this module.

Summary

Military chemical agents are extremely toxic and created to either injure or kill. Toxic industrial chemicals may be toxic and just as deadly. Fortunately, these chemicals can be detected, ensuring people can be protected and treated. They can be discovered through:

- Signs and symptoms.

- Chemical detection/identification equipment.
- Using the appropriate protective equipment provides protection. First aid measures are available such as atropine and 2-pyridine aldoxime methyl chloride (2 PAM chloride).
- Decontamination or removal and neutralization without requiring any exotic or unusual equipment.
- Hazard prediction is only an estimate; reconnaissance will confirm the hazard.

Appendix A

Place a mark in the box to indicate if the body system is impacted by the mechanism of harm.

Exercise: Identifying Mechanisms of Harm Effect

	Mechanisms of Harm						
	Thermal	**Radiological**	**Asphyxiant**	**Chemical**	**Etiologic**	**Mechanical**	**Psychological**
Body System							
Neurological							
Circulatory							
Reproductive							
Musculoskeletal							
Digestive							
Skin							
Renal							